WRP Technical Note HY-EV-2.2
January 1993

Wetland Groundwater Processes

PURPOSE: This technical note summarizes hydrologic and hydraulic (H&H) processes and the related terminology that will likely be encountered during an evaluation of the effect of ground-water processes on wetland function. This technical note provides general guidance to personnel in the field who lack specific expertise in H&H processes but are still faced with the regulatory responsibility of wetland permit evaluation. Future technical notes will complement this overview by presenting more detailed information on data sources and methods of analyses associated with individual H&H processes.

BACKGROUND: The hydrologic and hydraulic characteristics of a wetland influence all wetland functions, and consequently should be an initial focus of an evaluation. The processes by which water is introduced, temporarily stored, and removed from a wetland are commonly known as the water budget. Water is introduced to a wetland through direct precipitation, overland flow (or runoff), channel and overbank flow, groundwater discharge, and tidal flow. Temporary storage includes channel, overbank, basin, and groundwater storage. Water is removed from the wetland through evaporation, plant transpiration, channel, overland and tidal flow, and groundwater recharge.

The relative importance of groundwater processes on the water budget varies with the wetland type (i.e., riverine, tidal, depressional), and regional factors such as climate, hydrogeology, and physiography. Useful reviews of the influence of groundwater processes in wetlands can be found in Carter and Novitzki (1986) and Winter (1988). To evaluate whether groundwater at a site influences wetland functions, it is important to understand individual groundwater processes, the role they can play in various wetland types, and how to evaluate their contributions to the water budget.

FACTORS AFFECTING GROUNDWATER FLOW: Groundwater flow is influenced by a number of factors, including hydraulic gradients, hydraulic conductivity, porosity, and storage coefficients. While these parameters are simple to understand, they are often difficult to quantify. Information on local and regional soil parameters and piezometric heads can usually be obtained through state and Federal Geological Surveys or the Soil Conservation Service (SCS). Data sources include databases such as the U.S. Geological Survey WATSTORE, state wetland inventories, soil surveys, and SCS soil maps.

- Hydraulic Gradients. The hydraulic gradient is the difference in piezometric head between two locations divided by the distance between them. Generally, this is measured by installing several wells, bore holes, or piezometers, and measuring the head in each. For groundwater flows to or from the surface water, the elevation of the surface water is the upper piezometric head.

- Hydraulic Conductivity. This is the ability of the soil to conduct water under hydraulic gradients. The hydraulic conductivity or permeability depends on soil characteristics such as type (i.e. clay or sand), size, shape, and packing. Hydraulic conductivity can be estimated in a number of ways (Driscoll 1986, Lamb and Whitman 1969). It can be roughly estimated, given the soil composition and texture, or calculated based on a soil size analysis. Local values of hydraulic conductivity can be measured by performing a slug test in a piezometer or well location. Field-wide measurements can be determined from an aquifer performance (pump) test, in which one well is pumped and the variation of the piezometric head in nearby wells is observed over time. Values

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of hydraulic conductivity have been found to range from 10^{-8} meter per second in clay soils to 10^{-2} meter per second in well-sorted gravel formations (SCS 1992).

- Porosity. Porosity is the fraction of a soil volume occupied by voids, and represents the potential area through which water can flow. It is usually measured in the laboratory from a soil sample, although knowledge of the soil type can give a fair estimate of porosity. Together with the flow rate calculated from Darcy's Law (Freeze and Cherry 1979), the soil porosity can be used to estimate groundwater travel times.

- Storage Coefficient. The storage coefficient is a measure of the amount of water stored in an aquifer for a unit rise in the elevation of the piezometric head. For an unconfined aquifer, the storage coefficient (or specific yield) determines the rate of change in elevation of the water table. Values of this parameter can be estimated, crudely, from a knowledge of the soil material. However, the most reliable estimates of formation storage coefficients are usually determined from aquifer performance tests.

H&H PROCESSES. The primary H&H processes that influence wetland groundwater interaction are precipitation, infiltration, groundwater discharge/recharge, shallow and deep groundwater flow, groundwater pumping, and evaporation and transpiration. A schematic showing the relationship between these processes is shown in Figure 1.

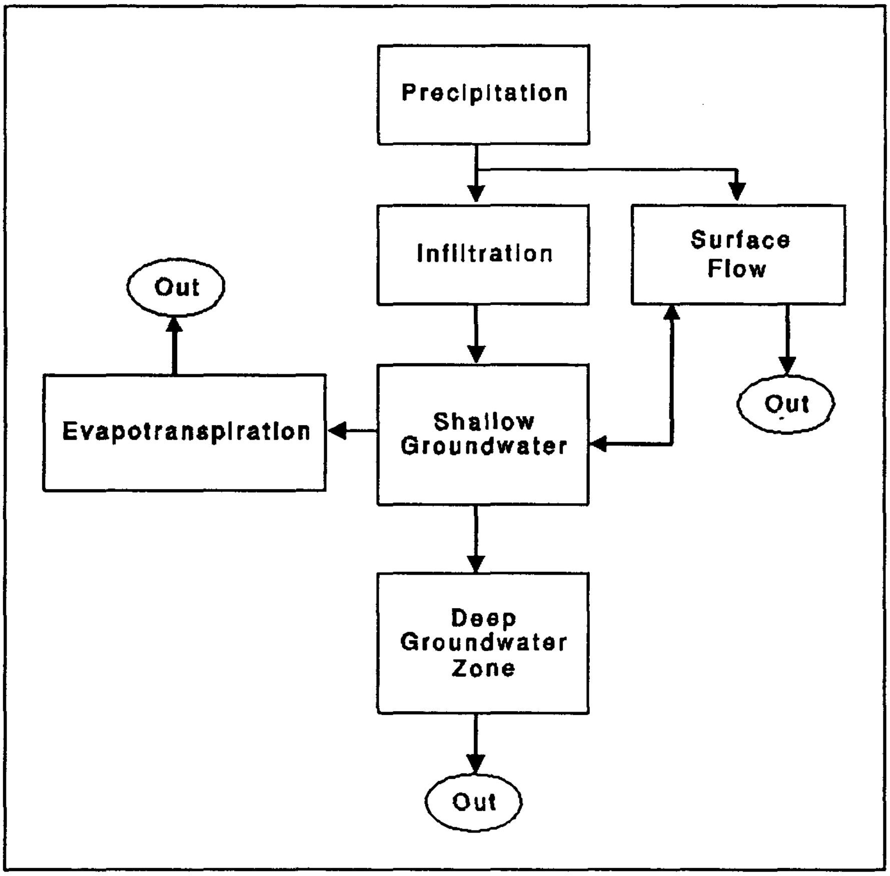

Figure 1. Flowchart of groundwater H&H processes

- Precipitation. Groundwater processes associated with wetlands result from local and regional precipitation patterns. Precipitation can influence a wetland water budget directly through rain and snowfall within the physical boundaries of the wetland, or indirectly through inflows from upstream watersheds. Information required to estimate the influence of precipitation ranges from the regional and seasonal variability to the frequency and magnitude of individual storm events. Complete daily records and statistical summaries of regional meteorological conditions are available through the National Weather Service.

- Infiltration. In areas where the surface water is not in direct hydraulic contact with the groundwater, surface water moves generally vertically downward through the unsaturated zone to the saturated zone (i.e., water table), or a perched water level above an impervious soil layer. The infiltration rate is governed by a number of factors, including the depth of surface water, the initial soil moisture content, and soil properties such as hydraulic conductivity. Infiltration and subsequent groundwater recharge are generally more important for upland and depressional sites, where stream inflows may not be the major factor creating the wetland. Sites with low-permeability soils may result in overland flow to the wetland or stream, whereas high-permeability soils can lead to significant infiltration to the underlying groundwater system. Where significant infiltration exists, a rapid increase in the elevation of the local water table can occur. This situation is most likely near streams or depressional wetlands, where the surrounding water table is near the ground surface and the residual moisture content high. The resulting high gradients from the groundwater system to the stream or wetland can cause significant groundwater discharge. Infiltration rates are estimated by direct measurements such as percolation tests and analytic methods (Chow 1964).

- Groundwater Discharge and Recharge. Groundwater discharge occurs where the elevation of the water table (piezometric surface) exceeds that of the surface water. Groundwater recharge results when the opposite occurs. Estimates of the rate of groundwater discharge or recharge can be obtained by applying Darcy's Law. The data required for this evaluation are synoptic surface water elevations, groundwater elevations or piezometric heads, and the hydraulic conductivity of the soil or sediment. At some sites, for example within the Prairie Pothole region, the deposition of organic material in the permanent pool may significantly reduce the local hydraulic connection to the groundwater system. However, hydraulic conductivities in the adjacent areas may be significantly larger, and become important as the water level in the wetland rises. In addition, wetlands have been observed to change seasonally from discharge to recharge or flow-through systems. As a result, it is important to examine both the spatial and temporal variability of wetland groundwater characteristics.

- Shallow Versus Deep Groundwater Flow. The interaction between the shallow groundwater zone and the underlying regional groundwater system can influence the rate of shallow groundwater transport, and thus the interaction with surface waters and wetlands. In some systems, an aquitard (i.e. confining layer) exists that decouples the shallow and deep groundwater zones. In these cases it is important that local shallow-water well piezometric heads (as opposed to regional groundwater data) are used to assess wetland groundwater function. On the other hand, hydraulically coupled aquifers can exhibit upward or downward flow depending on the relative piezometric heads and spatial variations in soil and sediment properties. The potential influence of the deep groundwater zone can be examined by inspecting available stratigraphic information for evidence of aquitard material or other significant changes in formation composition. This process can be further examined utilizing measurements of head from shallow piezometers and deep wells to develop piezometric contours of the system.

- Groundwater Pumping. Groundwater pumping or pump-recharge can influence groundwater processes in the vicinity of a wetland by altering the piezometric surface, and thus hydraulic gradients. Evidence of pumping can be seen in piezometric contours, or records obtained from agricultural extensions, Geological Surveys, and the Departments of Health or the Environment. In areas where pumping is used for irrigation, pumping is often seasonal, and the effects on shallow groundwater movement can vary. In addition, irrigation supported by deep-water well pumping may increase infiltration to near-surface aquifers.

- Evaporation and Transpiration. Evaporation from the groundwater zone occurs only when the water table is within a few inches of the ground surface. Evaporative losses depend on meteorological conditions such as air temperature, humidity, and wind speed, ground conditions such as vegetative cover, and the soil moisture content.

  Transpiration results from root uptake by emergent plants and the subsequent loss through leaf surfaces. Over extended dry periods, transpiration can cause the water table to decline as far as the deep root zone of the wetland vegetation. Estimates of transpiration rates are related to meteorological conditions, vegetation characteristics, soil moisture content, and the depth to the deep-root zone. These data are available through state agricultural extension offices.

  Often the effects of evaporation and transpiration on a wetland water balance are combined into a single estimate of water loss called evapotranspiration (ET). In depressional wetlands, where there is no significant outlet, and in wetlands where the water table is often close to ground surface, ET may be the most significant factor in removing water from the system. A number of methods for estimating potential or actual evapotranspiration at the ground surface are presented in the literature (Christiansen 1968; Kadlec, Williams, and Scheffe 1986).

CONCLUSION: This technical note provides a framework for examining groundwater processes within a wetland. The information and supporting references presented can be used by field personnel as a guide to (1) identifying the H&H processes that significantly influence wetland function, (2) understanding the interrelationships among the various H&H processes, and (3) identifying the data required to determine the relative importance of individual H&H processes. In general, the overview provided in this technical note should be used to avoid the possible omission or misinterpretation of specific H&H mechanisms and their role in determining the overall water budget of a wetland.

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